U.S. DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

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OUTLOOK FOR THE MACKEREL FISHERY IN 1933 [1]

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INTRODUCTION [2]

In exercise of its primary function, that of ascertaining what decrease, if any, has taken place in our food fishes, and finding remedies herefor, the Bureau of Fisheries has maintained, for the past seven ears, a special record of the mackerel fishery in order to discover the easons for the great fluctuations of this important food fish and to etermine whether anything might be done to ameliorate the severe ffects of the sharp fluctuation in its yield.

Such fluctuations have been truly remarkable as may be seen from ıe production curve in figure 1. In 1884 the salt mackerel fleet of ew England alone landed a quantity equivalent to 128,000,000 ounds of the fresh product, while in 1910 the entire mackerel fleet aught only the equivalent of 4,000,000 pounds of fresh mackerel. ı recent years the catch has averaged above 40,000,000 pounds, ut with fluctuations that have been sufficient to disturb greatly ıe market and price structures. The data appear in table 1. It emains to be seen whether during the next decade or two there may ot be repeated such extremes of scarcity as in 1910, or such heights f plenty as were prevalent in the early 80's.

Although the investigations indicate possible means of preventing r at least modifying the extremes of scarcity, the understanding of

[1] Approved for publication, May 5, 1933.

[2] This is the third of a series of reports giving annual forecasts of prospects for the mackerel fishery. The st appeared as Fisheries Circular No. 4, August 1931 and the second as Fisheries Circular No. 10, June 32. In order to conserve space in this report, some parts of the explanatory and descriptive sections that peared in the previous circulars have been omitted.

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the natural economy of the species and the relation between intensity of fishing and mortality [3] is not yet sufficiently complete to warrant action in this direction. In the meantime, a certain protection against the ill effects of violent fluctuations in yield might be afforded if such changes could be predicted with sufficient reliability to permit

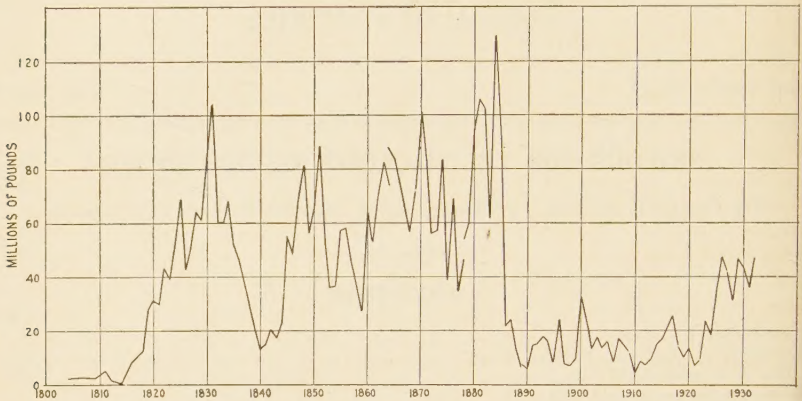

FIGURE 1.—Annual catch of mackerel by American vessels, 1804–1932. Data for 1804 to 1864 consist of tota quantity of salt mackerel inspected in Massachusetts; data for 1864 to 1878 consist of the salt mackere inspected in New England; data for 1878 to 1889 consist of the catch of the salt mackerel fleet of Ne England; data for 1889 to 1905 consist of the catch of the salt mackerel fleet of New England plus fres mackerel receipts in Boston; data for 1905 to date consist of the total landings of the American macker fleet. All quantities were converted to the basis of fresh round mackerel.

some advance adjustment of the fishing operations, marketing chan nels, and processing means.

TABLE 1.—*Annual landings of the mackerel fleet 1924 to 1932*

[Figures in thousands of pounds; that is, 000 omitted]

Year	By seiners	By netters		Total
		Spring and summer	Autumn	
1924	16,466	1,481	288	18,2
1925	31,435	2,169	563	34,1
1926	44,605	1,859	245	46,7
1927	40,006	1,223	584	41,8
1928	26,816	2,222	1,946	30,9
1929	42,234	3,365	567	46,1
1930	37,924	4,240	993	43,1
1931	33,324	1,800	1,359	36,4
1932	43,920	972	1,879	46,7

NOTE.—Statistics for the years 1924 to 1927, inclusive, revised since original publication.

The purpose of this circular, therefore, is twofold. First, to assem ble, interpret, and make public such facts as are available as to th probable abundance of mackerel in 1933; and second, to add anothe year's record to the series already started, from which there shoul ultimately result an appraisal of the reliability and usefulness to th industry of such preseason surveys of the mackerel prospects. Whi

[3] For a discussion of this matter consult Progress in Biological Inquiries, 1932.

ere can be very little doubt as to the accuracy of the facts herein esented, their interpretation is subject to more or less high degree uncertainty; hence, the necessity of setting forth, in considerable tail, the data and reasoning that underlies the conclusions.

CAUSES OF CHANGES IN YIELD

There are three things that affect the total annual yield of the ackerel fishery. First and most fundamental is the number of ackerel in the sea; second is the degree to which these are accessible the fishermen; and third, the amount of fishing effort employed in tching them.

Abundance.—It will be convenient to express the number of mack-el in the sea as their "abundance" and employ this term only in this stricted sense. Abundance then can vary only according to the cess of reproduction over mortality or vice versa. As will be shown ter, there is great variation in the numbers of mackerel added to the mmercial stock in the sea each year. The mortality rate, on the her hand, is more nearly the same from year to year. Therefore, e abundance fluctuates mainly according to the number of young lded to the stock by each year's spawning. By determining the e of mackerel in samples taken from the commercial catch it is ssible to arrive at the relative importance of previous years' addi-ons to the stock and also the rate of decline of each contingent in bsequent years.

Accessibility.—The degree to which the mackerel are accessible the fishery varies from time to time and place to place. Off the uth and west coasts of England it was found by Allen[4], and Russell[5], at the years having the greatest amounts of sunshine in February d March afforded the best fishing in May and June. This, pre-mably is because sunny springs are favorable to the growth of inute plant life, which in turn provides sustenance for the "red ed" and small "shrimps" which by May and June become abun-nt in that area and attract the feeding mackerel in large numbers, ndering them unusually accessible, thus causing larger catches in ars in which a sunny February and March starts this chain of ents most favorably. In the Kattegat and Skagerak, Johansen [6] s found that in years with unusual penetration of the North Sea ater in spring, the surface waters become cooler than usual in sum-er and the catch of mackerel is better. Similarly Jensen [7] has own a close correlation between September water temperature and ackerel landed at Copenhagen from the sound and eastern Baltic uring September.

There may be similar influences of weather and water conditions the accessibility of mackerel in American waters. For instance: years when water temperatures at the Boston lightship have eraged high during early December the catches by netters in

[4] Allen, E. J. Mackerel and Sunshine. Journal, Marine Biological Association, N.S., vol. 8, 1907–1910, . 394–406.

[5] Russell, E. S. Report on log-book records relating to mackerel, pilchards, and herring, kept by fishermen ring the years 1895–1911. Board of Agriculture and Fisheries, Fishery Investigations, series II, vol. III, . 1, 1915.

[6] Johansen, A. C. On the influence of the currents upon the frequency of the mackerel in the Kattegat d adjacent parts of the Skagerak. Meddelelser fra Kommissionen for Danmarks Fiskeriog Havunder-elser. Series: Fiskerie, band VII, no. 8, 1925.

[7] Jensen, A. J. C. On the influence of hydrographic factors upon the yield of the mackerel fishery in the nd. Report of the Danish Biological Station. Copenhagen, 1930.

Massachusetts Bay and adjacent waters in November and December have been best. The evidence on this appears in table 2 and figure 2. In the spring season, periods of moonlight nights furnish the best fishing for netters, and when these occur near the middle of this season, it appears to have exceptionally favorable effects on their catch. These peculiarities are shown in figure 3. Other relationships may come to light when there has been opportunity of studying in greater detail the relation between mackerel catches and meteorological or hydrographic conditions.

Availability.—The two influences on catch, abundance, and accessibility, together constitute the availability of mackerel to the fleet

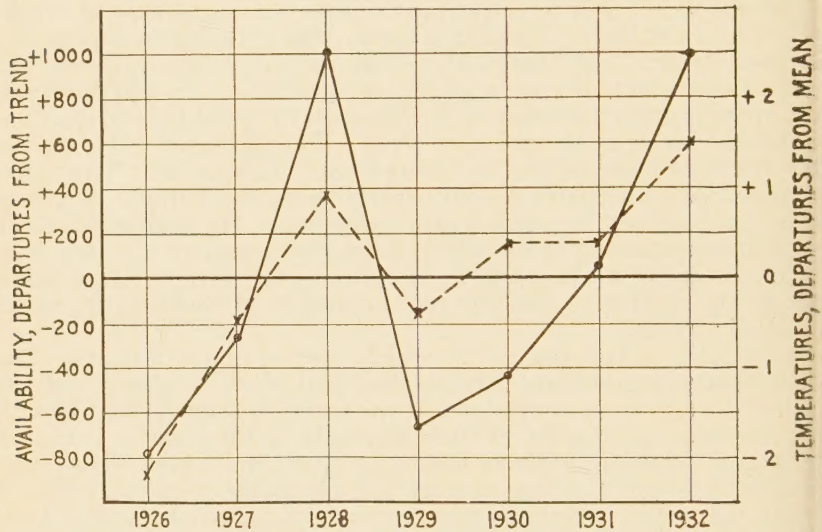

FIGURE 2.—Comparison of departure from the trend of catch of 1921-class mackerel in the fall net fishery and departures from the average of temperature of the water at the Boston lightship, showing that large catches are made in the autumns with warmer water. Temperature is shown by the dotted line. Data from table 2.

Taking each season as a whole, abundance has a more profound influence on availability than has accessibility. The latter may influence the catch greatly at certain times and places, but such local and transitory effects do not appear to have altered the total catch as greatly as have the changes in abundance.

TABLE 2.—*Relation between fluctuations in availability in the autumn net fishery and fluctuations in water temperature*

Year	Index of availability, 1921 class	Trend of index of availability	Departures from trend of index of availability	Mean Fahrenheit temperature Dec. 1–15, surface water at Boston Lightship	Departure from 7-year mean
1926	754	1,540	−784	42.7	−2
1927	1,136	1,400	−264	44.4	−
1928	2,308	1,300	+1,008	45.8	+
1929	525	1,190	−665	44.5	−
1930	650	1,090	−440	45.3	+
1931	1,051	1,000	+51	45.3	+
1932	1,892	901	+991	46.4	+1

Fishing effort.—Whatever the conditions of availability may be, here is a further influence on the catch; that is, the number and kind of vessels engaged in the fishery each year and the persistence with which they fish during the season. Obviously, an increase in

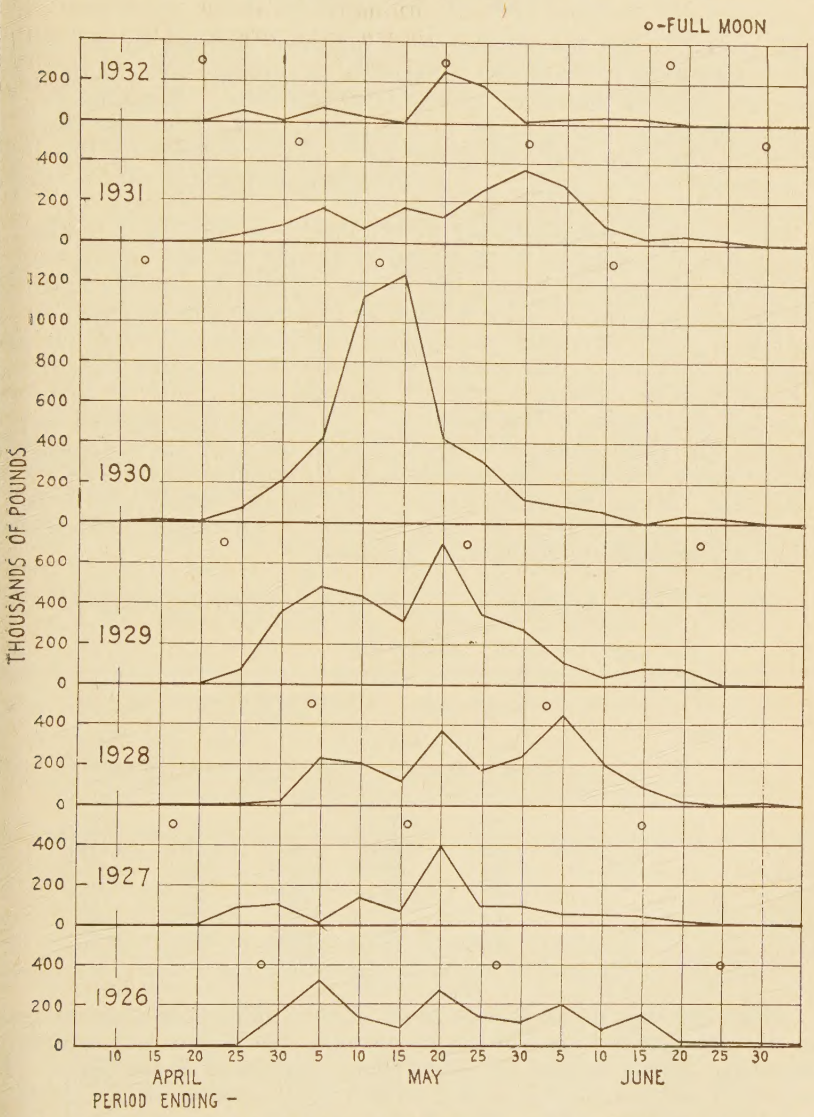

FIGURE 3.—Landings by netters, each 5-day period, spring season, 1926 to 1932, showing that mackerel were caught mainly during full-moon period. Dates of full moon indicated by the circles.

the number of vessels, an increase in their efficiency or their participation during greater portions of the season must result in a larger catch if availability remains constant. With a great variety of vessels in the fishery, some fishing one year, some another, some fishing part of the season, others fishing all of the season, it is very difficult to assign any value to the total fishing effort. Some part of the confusion

has been avoided by considering separately the two principal types o fishing—seining and netting—and dealing separately with the sprin and the fall netting seasons.

INDEX OF AVAILABILITY

Since it has not been possible to measure changes in the fishin effort, and since it is equally impossible to foresee such changes, an forecast must be based on probable availability. Fortunately, th modifications in fishing effort in the past have had far less effect o the yield than the availability has had. The evidence on this poin will appear in later pages. It is, therefore, important that a reliabl measure of availability be devised.

This has been accomplished by employing a statistical method c measuring the changes in availability similar to one often used i expressing changes in commodity prices. This consists of computin the geometric mean of rates of change in catch from one year to th next of a group of vessels that fished continuously throughout eac season in both years, and linking such pairs of means to a base year t provide a series of index numbers.[8] For the sake of brevity this seri is called the "index of availability." It should be regarded as po trayings only those changes in catch that would have taken place if th same vessels had been fishing regularly throughout the entire seaso each year during the entire period. Stated differently, the index c availability gives a view of the composite of abundance and access bility undistorted by changes in the fleet.

TABLE 3.—*Indices of availability, by weight and by number, 1924 to 1932*

[1926=1,000]

Year	Seine fishery		Net fishery, spring and summer		Net fishery, autumn	
	By weight	By number	By weight	By number	By weight	By numb
1924	541	865				
1925	871	1,026				
1926	1,000	1,000	1,000	1,000	1,000	1,0
1927	970	909	1,109	1,094	1,377	1,3
1928	556	521	1,503	1,419	2,710	2,5
1929	897	1,273	1,625	1,995	601	5
1930	800	903	1,849	2,191	1,025	1,0
1931	612	662	1,059	1,232	1,569	1,4
1932	788	1,257	690	791	3,116	2,8

Although this index is free from effects of increases or decreas in the number and kind of vessels fishing, still it does not complete eliminate effects caused by other than changes in availability. Th reason it fails to do this is that it is a computation of the catch p vessel per season. Even though the vessels employed in the comp tation worked throughout the entire season each year, the amount time each vessel spent in actual fishing varied from year to yea There are a number of causes for such variations. Most obvious a the interruptions to fishing caused by stormy weather, to repairin of machinery and gear, and the like. These are not regarded as

[8] This is an adaptation of the method described by Chaddock, Principles and Methods of Statisti Houghton Mifflin Co., 1925, p. 189.

erious effect for they are more or less random occurrences and should verage about the same from year to year for a group of vessels. But n additional influence on fishing time, and one that is not random, is he fact that in years when mackerel are abundant catches are made nore frequently and a distinctly larger percentage of the fleet's time s devoted to the landing of fares and to sailing to and from the fishing rounds, with a consequent reduction of time spent in actual fishing. Hence, the index of availability under-rates the good years and over-ates the poor years.

To appraise this effect is difficult, on account of the lack of adequate ata on the amounts of time spent in actual fishing by the entire eet or even a portion of the fleet. However, thanks to the kindness f certain of the fishermen in keeping a detailed log of their activities, ome notion of this effect may be gained with reference to the years 931 and 1932. In table 4 are given summaries of the activities of ve vessels having adequate records of their operations during the najor portion of both seasons. We see from this summary that all ve vessels spent a smaller percentage of time in actual fishing in 932 than in 1931, the decrease lying between 9 and 19 percent. 1931 as a year in which the mackerel were moderately plentiful and 932 a year in which they were very plentiful. Hence, it is clear that he fleet spent less time actually fishing in the year of greatest plenty. Iow much less time was so spent by the fleet cannot be stated pre-isely, for five vessels are too few to give a reliable average; but it eems reasonable to suppose that the decrease of fishing time on the hole might be in the neighborhood of 15 percent. Thus it appears hat although the index of availability indicated a 30 percent increase n 1932 over 1931, the real rate of change in availability should be earer 45 percent. Hence, in judging the significance of the index f abundance, it must be remembered that the higher values in the eries are below their real height, while the depressions are not shown o be as deep as they really are.

ABLE 4.—*Effect of increased availability in 1932 over that of 1931 in decreasing the amount of time spent in actual fishing*

Vessel	1931			1932			Percent decrease in fishing time in 1932 compared with 1931
	Total days at work [1]	Total days actually fishing	Percent of working time spent in actual fishing	Total days at work [1]	Total days actually fishing	Percent of working time spent in actual fishing	
o. 1	100	58	58	122	64	52	10
o. 2	128	88	69	151	85	56	19
o. 3	130	74	57	68	34	50	12
o. 4	142	106	74	129	80	62	16
o. 5	162	94	58	148	78	53	9

[1] Exclusive of periods when work was prevented by stormy weather or by laying up in port, but including ays spent in port for discharging cargoes and days at sea en route to or from fishing grounds.

FLUCTUATIONS IN AVAILABILITY

Seine fishery.—Considering first the catch by seiners which account or some 90 percent of the total landings, a comparison of total catch vith the index of availability, as shown in tables 1 and 3 and figure 4,

indicates that the year-to-year changes are about the same in both series. Hence, these changes in catch were caused not by alterations in the fleet but by differences in availability from year to year. On the other hand, the catch over the entire period has a horizontal or slight upward trend while the index of availability is distinctly downward in trend. It may be concluded, therefore, that there has been a gradual increase in the fishing effort through the 9-year period.

Since the availablity changes sharply from year to year, and the fishing effort changes gradually, the availability is the more important feature in determining the results of the fishery 1 year in advance.

As a result of measuring tens of thousands of mackerel from hundreds of fares each season and from studies of thousands of scales, it is possible to estimate rather closely the numbers of fish of each age in each year's landings. From such estimates it is possible to see the effect on availability, of the contributions to the mackerel stock by

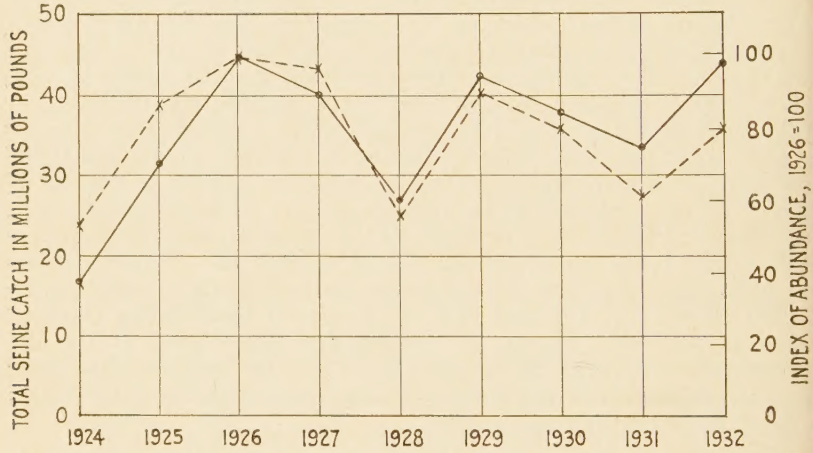

FIGURE 4.—Comparison of total catch with index of availability in the seine fishery. The catch is shown by the solid line; the index of availability by the dotted line.

each year class. This may be seen most readily in figure 5. The data are given in table 5. It is obvious that the generally high availability during the period 1925 to 1928 was caused by the abundance of mackerel of the 1923 class (i.e., mackerel produced by the spawning season of 1923). But with the failure of the 1924, 1925, 1926, and 1927 spawnings to produce many mackerel, the catch declined until the 1928 class came into the picture in 1929, not only halting the decline but causing an increase both in numbers and weight. Small contributions from the 1929 and 1930 classes in 1930 and 1931 were not sufficient to halt the decline resulting from the diminution of the 1928 and older classes; but in 1932, a great increase in the contribution of the 1930 class caused another sharp rise.

Hence, it is clear that fluctuations in availability depend on whether the new stock added to the population is in excess of the diminution of the older stock carried over from previous populations. Therefore if changes in the commercial yield are to be foreseen 1 year in advance it is most important to have a thorough knowledge of the abundance of each year class, and its probable rate of decline.

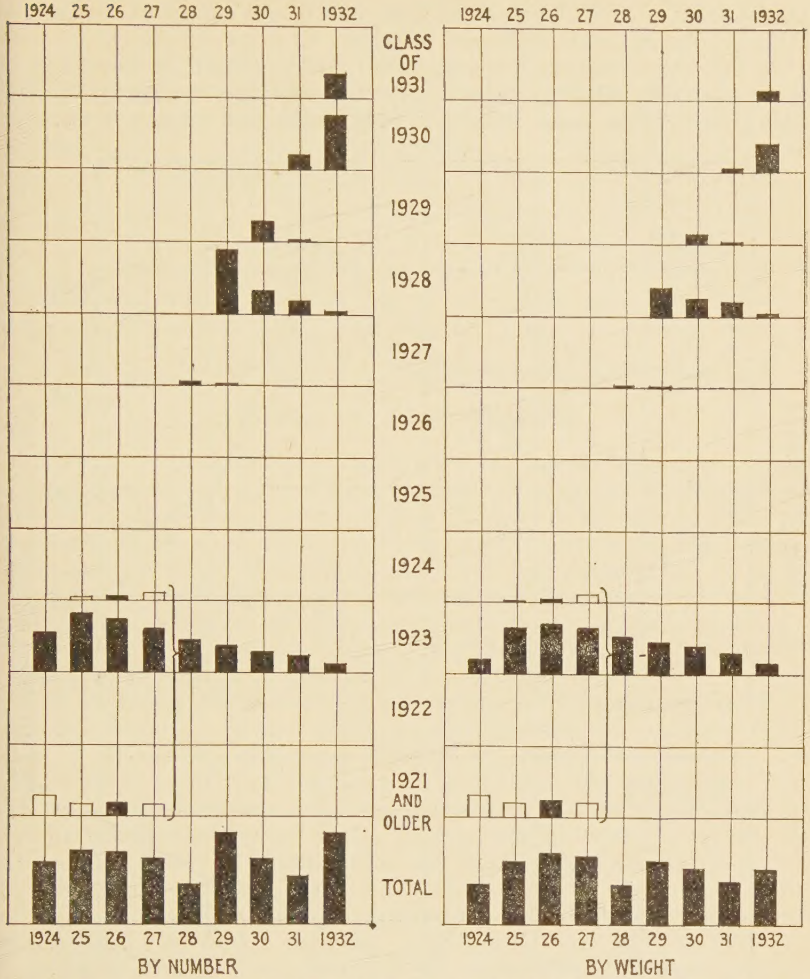

FIGURE 5.—Composition of the catch of the seine fishery, showing the influence of each year class on the stock of mackerel. Heights of bars are proportional to the index of availability. Solid black bars indicate the more reliable determinations; the open rectangles indicate that determinations were only approximate.

TABLE 5.—*Seine fishery: Indices of availability, by year classes, 1924 to 1932, inclusive*

[1926=1,000]

Year	Total number	Distribution by year classes									
		Old	1921	1923 [1]	1924	1927	1928	1929	1930	1931	Various
1924	865	[2] 74	[2] 223	568							
1925	1,026	[2] 32	[2] 137	829	[2] 28						
1926	1,000	32	162	734	69						[3] 3
1927	909	[2] 27	[2] 144	602	[2] 127						[4] 9
1928	521			454		64	3				
1929	1,273			372		20	875	6			
1930	903			298			311	294			
1931	662			235			186	26	209	6	
1932	1,257			127			42	4	760	324	

[1] After 1927 the 1924, 1921, and old classes are included in this column.
[2] Approximate value.
[3] 1925 class.
[4] 1926 class.

Net fishery.—A comparison of total catch and index of availability in the spring and fall drift-net fisheries, as given in figure 6, shows rather less resemblance between catch and availability than was the case in the seine fishery. Obviously, the size and composition of the netting fleet have been more variable than the seining fleet. De-

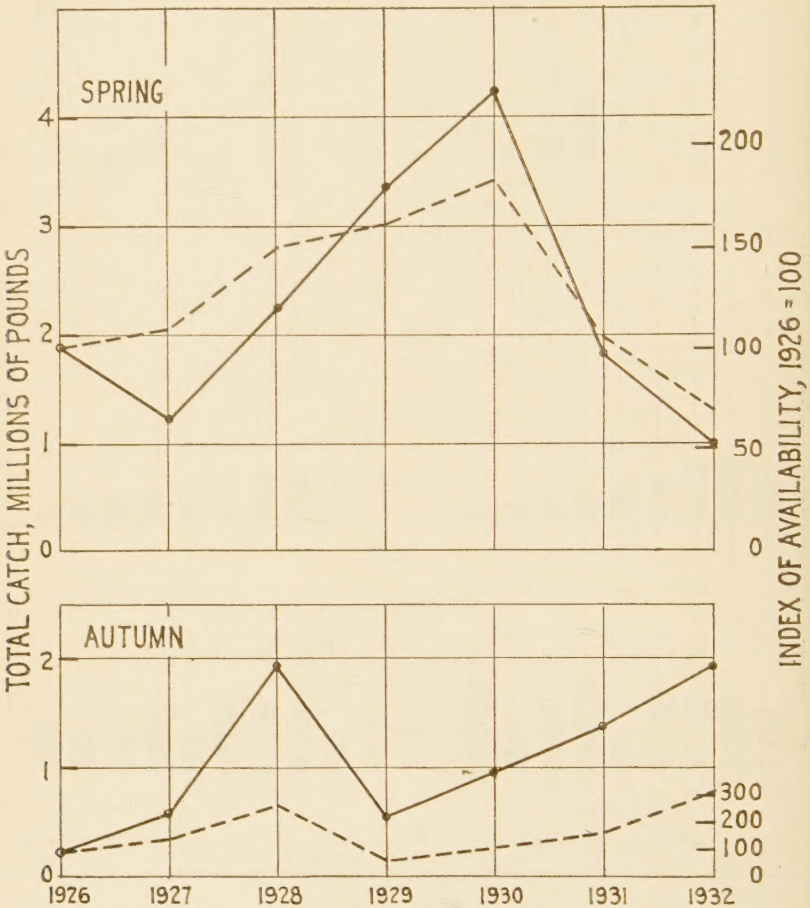

FIGURE 6.—Comparison of total catch with the index of availability in the net fishery. The total catch is shown by the solid line; the index of availability by the dotted line.

spite this, however, fluctuations in availability are still a major influence on the yield. If the year-class composition, as given in table 6, be examined, it is apparent that there is very little correspondence between rises in availability and the advent of broods. That is, the availability may increase without any additions to the stock. Hence, it appears that availability in this fishery is influenced more by accessibility than by abundance. The significance of this to predicting will become apparent in later sections of this circular.

TABLE 6.—*Net fishery: Indices of availability, by year classes, 1926 to 1932, inclusive*

[1926=1,000]

Year	Spring				Fall				
	Total number	Distribution by year classes			Total number	Distribution by year classes			
		1923 and older	1928	Various		Old	1921	1928	Various
1926	1,000	1,000			1,000	246	754		
1927	1,094	1,094			1,356	220	1,136		
1928	1,419	1,419			2,553	245	2,308		
1929	1,995	1,989		[1] 6	562	12	525		[1] 25
1930	2,191	2,136	55		1,026	16	650	360	
1931	1,232	1,121	110	[2] 1	1,454	25	1,051	378	
1932	791	688	99	[2] 4	2,864	149	1,892	800	[3] 23

[1] 1927 class. [2] 1929 class. [3] Classes of 1929 and 1930, 14 and 9, respectively.

TYPES OF YEAR CLASSES

It has been demonstrated that there are great differences in the contributions of the several year classes. Since these differences constitute the major influence on the catch it is necessary to determine the numerical size of each year class and to establish the usual or normal course of the changes in availability of a year class in successive years of life if future yields are to be foreseen. In figure 7 are plotted the indices of availability of those year classes which were represented in the catch in sufficient numbers to provide reliable data. A logarithmic scale was used so that the slopes of the lines represent rates of change. From the graph it is apparent that there have been marked differences in the changes in availability of the several year classes. The 1927, 1928, and 1929 classes decreased markedly year by year after their first appearance as yearlings in the fishery. The 1923 class, on the other hand, increased in availability from its first year in the fishery as yearlings to the second year as 2-year olds. Thereafter, there was a continuous decrease, but at a much slower rate than the classes of 1927, 1928, and 1930. For convenience in discussion, we shall apply the term "transitory" to the classes of the last-named type and shall call the 1923 class the "persistent" type. Although the 1930 class resembles the persistent type inasmuch as it increased in availability when 2 years old as compared with its availabilty when only a year old, it is not yet known what its subsequent rate of decline (or increase) may be, so it cannot yet be classified as to type. We have no analyzable data on the 1921 class, but the fact that the total catch increased in 1922 and decreased in 1923 leads us to believe that this class was of the transitory type.

In addition to the sharp contrast in the trends of availability of the two types, there are marked differences in geographical and seasonal distribution of representatives of each. The two largest year classes of the transitory type were the 1921 and the 1928 classes. Both of these have been characterized by appearing in the waters off Nova Scotia each June and in Massachusetts Bay and adjacent waters each November and December during the fall netting season.[9] On the

[9] That the 1927 and 1929 classes have not formed an important portion of catches taken along the Cape Shore or in the fall net fishery, is no evidence against this characteristic of the transitory type, for yearlings and 2-year olds are never taken (except as stragglers) in these branches of the fishery, and by the time the members of these particular classes became 3-year olds, their availability had decreased so markedly that their numbers would be imperceptible in our data.

other hand, the 1923 class, representing the persistent type, has neve been present in appreciable numbers in catches from these localitie during the above-specified portions of the seasons. The importanc

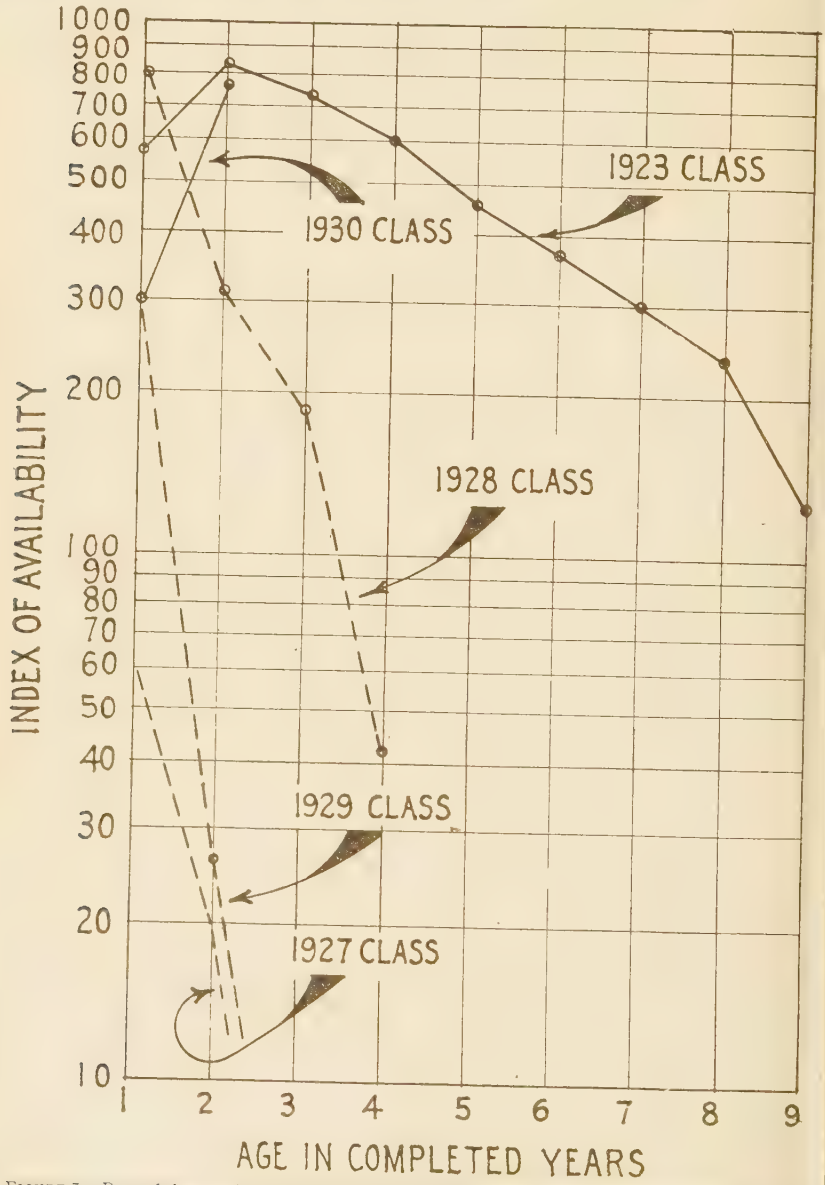

FIGURE 7.—Rate of change of the availability of the various year classes in the seine fishery. The vertical scale is logarithmic; data are from table 5.

of these differences in types of year classes will become apparent whe past experience in forecasting is reviewed, and in considering th prospects for the coming season.

PREVIOUS FORECASTS AND PRESENT DIFFICULTIES

The first attempt at forecasting was in the spring of 1928 when the 1923 and 1921 classes for 3 years had been observed to decline consistently. As there was no indication that a new year class was to appear, a further decline in the catch was predicted.[10] Subsequent events proved this diagnosis to be essentially correct. The year classes already in the fishery declined nearly the expected amount and although a new class, that of 1927, appeared, its numbers were not great enough to offset the decline of the other year classes.

In the spring of 1929 it was pointed out [11] that the 1923 and 1921 classes must continue to decline, but since there was no basis for determining the probable contribution of the 1927 class, no definite prediction was made. As it turned out, the 1927 class provided only small numbers, but another new class, that of 1928, was so abundant that the catch was markedly higher than in the previous year.

In the spring of 1930 when discussing the prospects for the coming season [12] it appeared that the outstanding question revolved about the 1928 class. On the basis of the previous year's catch it appeared that this class exceeded the 1923 class in abundance and for this reason a catch of 60,000,000 pounds appeared to be in prospect. (At that time the existence of two types of year classes was not in evidence.) As it turned out, the 1928 class furnished only a fraction of the anticipated amount and although the new class of 1929 augmented the catch, the season's total reached only 43,000,000 pounds, or 28 percent less than anticipated.

In outlining the prospects for the season of 1931 [13] it was concluded that the abundance of mackerel would be such as to provide a catch of 35,000,000 pounds exclusive of any contribution that might be made by the 1930 class. The catch of the predicted portion was 32,183,000 pounds, or within 8 percent of the anticipated quantity. The new class of 1930 furnished 4,300,000 pounds of blink and tinker sized mackerel, making the total catch 36,483,000 pounds.

The preseason survey of prospects for 1932 resulted in an estimate of 26,000,000 pounds of mackerel as the probable catch, exclusive of yearlings or tinkers.[14] As may be seen from table 7 the catch exclusive of tinker and smaller sizes was 21,788,000 pounds, or 18 percent below the predicted amount. This appears to be a fair agreement between prediction and actual catch, but it resulted not from correctly foreseeing the events of the 1932 season but from two quite unexpected features that happened to be of the kind that counterbalanced each other. One was the occurrence of mackerel of the 1930 class in numbers far above anticipation; the other, the unusually slow growth of these mackerel most of which failed to get above tinker size before the end of the season. Reference to tables 7 and 8 shows these features.

Whereas, it was expected that 1,900,000 mackerel of the 1930 class would be caught and that they would average 1.4 pounds, providing a catch of 2,700,000 pounds, it actually turned out that some 27,500,000 were caught and they averaged only 0.84 pound in weight, so that

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[10] Fishing Gazette, vol. 45, no. 4, April 1928.
[11] Fishing Gazette, vol. 46, no. 4, April 1929. Fishermen's Own Book and Fishing Equipment News, vol. 9, no. 3, March 1929.
[12] Fishing Gazette, vol. 47, no. 4, April 1930.
[13] Bureau of Fisheries, Fishery Circular No. 4, August 1931. (Approved for publication, May 25, 1931.)
[14] Bureau of Fisheries, Fishery Circular No. 10, June 1932. (Approved for publication Apr. 26, 1932.)

while the catch of this class aggregated 23,000,000 pounds only a smal part of this quantity consisted of mackerel that were above tinker size.

TABLE 7.—*Landings of the mackerel fleet in 1932, by year classes and by siz categories*

[Figures in thousands of pounds; that is, 000 omitted]

Year classes	Under 0.5 pound (tacks)	0.6 to 0.9 pound (blinks and tinkers)	1.0 pound and over (mackerel)	Total
Old classes			12,048	12,04
1928 class			3,353	3,35
1929 class			273	27
1930 class	32	16,938	6,090	23,06
1931 class	286	7,727	24	8,03
Total	318	24,665	21,788	46,77

TABLE 8.—*Comparison of prediction and catch of the mackerel fleet in 1932*

[Quantities in thousands of pounds; that is, 000 omitted]

Year classes	By number		Average weight		By weight	
	Predicted	Caught	Predicted	Actual	Predicted	Caugh
PREDICTED PORTION						
Old classes (1923 dominant):	*Number*	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pound*
By seines	6,000	4,653	2.10	2.11	12,600	9,84
By nets:						
Spring and summer	800	374	2.12	2.09	1,700	7
Fall	200	630	2.25	2.27	500	1,42
Total	7,000	5,657			14,800	12,04
1928 class:						
By seines	3,900	1,560	1.80	1.76	7,000	2,75
By nets:						
Spring and summer	200	86	1.84	1.79	400	1
Fall	200	246	1.87	1.83	400	44
Total	4,300	1,892			7,800	3,35
1929 class:						
By seines	600	167	1.57	1.52	900	25
By nets:						
Spring and summer		10		1.41		1
Fall		5		1.45		
Total	600	182			900	27
1930 class:						
By seines	1,900	27,541	1.40	.84	2,700	23,03
By nets:						
Spring and summer		19		1.05		2
Fall		3		1.13		
Total	1,900	27,563			2,700	23,06
UNPREDICTED PORTION						
1931 class, by seines		11,896		.68		8,03
Total, predicted portion	13,800	35,294			26,200	38,73
Total, unpredicted portion		11,896				8,03
Grand total		47,190				46,77

Further examination of table 8 will show that the older mackerel were caught in much smaller quantities than anticipated. This resulted, not from an incorrect diagnosis of their abundance, but from the effect of the extraordinary numbers of mackerel of the 1930 class available to the seine fleet. In the discussion of the index of availability it has been pointed out that unusual availability decreases the amount of fishing time even though the same number of vessels are engaged in the fishery. In this particular instance there is reason to believe that there was a still further diversion of fishing effort in such a way as to reduce the catch of large mackerel below the amount indicated by their availability. In 1932 the young mackerel of the 1930 and 1931 classes were present in dense schools enabling good catches to be made in few sets, while the older mackerel, if we may judge from the fishermen's log books, were more scattered, and in smaller schools. Although the latter brought much better prices, the sureness of a catch of the younger mackerel doubtless caused greater concentration of effort on these, and greatly limited the time spent looking for the more elusive large mackerel. Hence, the decline in catch of large mackerel undoubtedly was much exaggerated in relation to their real availability. This is further proven by the results of the net fishery in the spring. In this branch of the fishery which did not have its attention diverted by the abundance of mackerel of the 1930 class because the latter were too small to be caught in its gear, the older classes were caught in the predicted amounts (when sharp reduction in the size of the spring netting fleet is taken into account).

Thus, it appears that the prospects of the 1932 season were correctly foreseen as far as the older year classes were concerned, but the young class of 1930 appeared in unlooked for quantities, causing the catch to be much larger than the anticipated amount.

In reviewing the 5-year series of predictions, it is apparent that the two principle sources of difficulty have been the lack of information as to the probable number of yearling mackerel due to appear and the difficulty in anticipating the quantities likely to be contributed by those year classes that cannot yet be classified as to type; that is, whether they are of the transitory or persistent type. In the past, two predictions, 1930 and 1932, were materially in error due to these two difficulties, and in two predictions, 1928 and 1931, these sources of error did not enter, so that there was almost perfect agreement between forecast and catch. In the remaining case, the forecast of 1929, the uncertainties were sufficiently evident to prevent a definite prediction.

Hence it would appear that in the present state of our knowledge the opportunities of arriving at a reliable preseason estimate may differ from year to year. For the past several years, we have been fully aware of the uncertainties introduced by the lack of prior knowledge of the probable abundance of the yearling stock of mackerel, and have made surveys of the spawning grounds in order to develop means of arriving at an early estimate of the numerical importance of the current season's year class by means of estimating the numbers of young mackerel surviving their critical early stages of existence. The laying up of the Bureau's research ship *Albatross IV*, for lack of operating funds, has caused this type of study to cease. Until it is resumed, we are forced to omit the yearling fish from the

predictions. Yearling fish are of blink and tinker sizes, while 2-yea olds are usually of a size accepted by the trade as "small" or "medi um" mackerel. Hence this year's forecast must be limited to th catch of that portion of the mackerel stock of greater than yearlin age and usually larger than tinker size.

The second source of difficulty, which is the uncertainty as to typ of year class, concerns the 1930 and 1931 classes. Both of these wer important in the last season's catch (1932) and must be taken int account in appraising the prospects of 1933. There are some sligh evidences as to the type to which these year classes belong, but sinc the evidence is not conclusive, it has been found necessary to allo latitude for the event that they may prove to be of types other tha are indicated by present facts. This results in offering a "mos probable," a "highest probable," and a "lowest probable" estimat of catch for 1933.

PROSPECTS FOR 1933

In estimating the prospects for the season of 1933 it is necessar to limit consideration to the probable effects on yield of changes i availability as defined above. There will be no attempt made t anticipate the effects of economic influences which may alter the siz of the fleet or the intensity of its activities. In other words, it will b assumed that the fleet remains the same size and fishes with the sam degree of activity as in 1932. If there are changes in these respect the catch may be expected to be altered accordingly.

MOST PROBABLE ESTIMATE

The estimate of catch for 1933 that appears most probable on th basis of present information hinges on the assumption that the 19 class is of the persistent type and will be subject to slight decreas and that the 1931 class is of the transitory type and will decrea markedly. The others, 1928, 1923, and minor classes, are definitel expected to decrease at rates consistent with those experienced b these classes in previous years. We shall take these up in orde beginning with the oldest about which we have most information.

Older year classes.—In this category it is necessary to group th classes, 1921, 1923, and 1924, for these are not separable by metho now available. The 1923 class is dominant among them comprisin perhaps at least 75 percent, if not more, of all mackerel included und this title. During past years this class has been very important i the seine fishery and in the netting fishery during the spring seaso On the other hand, the net fishery in the fall has never taken macker of this class in appreciable quantities, but has taken mainly macker of the 1921 class.

The group in which the 1923 class is dominant has been a highl important contributor to the seine catch for the past 9 years. I changes in availability to this type of gear are shown in figure 7 fro which it may be seen that since its fifth year the rate of decline h been almost constant with the exception of the change in passing fro its eighth to its ninth when a sharper drop occurred. This last shar drop we believe owing to diversion of attention from the mackerel this group to the smaller and much more numerous mackerel of th

1930 class. This has been discussed at length in preceding paragraphs. Therefore, we may conclude that the normal rate of decline of availability of this class to seiners is more nearly in accordance with its decrease during the years 1928 to 1931 when the decline averaged 20 percent per annum. Since, in forming the "most probable" estimate, we are assuming the abundance of mackerel of the 1930 class to be roughly equal to that of 1932, the diversion of attention from the older classes should be similar to that in 1932, and we may apply the average rate of decline to the 1932 total catch of these older classes. This total was 4,653,000 mackerel; a reduction of 20 percent would leave 3,700,000 mackerel as the most probable number to be caught by the seining fleet in 1933.

An estimate of the availability of mackerel of the older classes in the net fishery of the spring season is more involved than in the seine fishery, because of the greater effect of accessibility in the yield. As has already been pointed out, coincidence of moonlight nights with the crest of good fishing greatly effects the availability of mackerel in this fishery. As a result of allowances made for these effects last year, our estimate of the most probable availability of this year class was 70 percent of the 1926 level. Actually the availability was 61 percent of the 1926 level. Had the netting fleet continued at the same size as in the previous year, this would have provided a catch very close to the predicted number of 800,000 mackerel. But instead of the fleet remaining at the same size, less than half as many vessels participated in this branch of the fishery, the average number landing fish per half-month in 1932 being 12 as compared to 27 in 1931. As a result of the curtailed fishing effort, only 374,000 were caught.

Judging from the correspondence of the dates of full moon with the usual period of best net fishing, the 1933 season promises conditions of accessibility to the netters similar to those of last year. Using this assumption, and applying the same rate of decline as was used for this year class in the seine fishery, and assuming the fleet to be of the same size as in 1932, we arrive at 300,000 mackerel as the most probable estimate of catch in the net fishery during the spring of 1933. Of course, if the fleet should change from the 1932 level, the catch would be correspondingly higher or lower as the case might be.

The autumn net fishery differs from that of the spring season in that the 1921 class instead of the 1923 class has been dominant in the stock of mackerel upon which this fishery draws. It differs also in having a more fluctuating yield, caused, we believe, by the relatively greater effect of variations in water temperatures, or oceanographic conditions related to water temperatures, as has been shown in figure 2. On account of this influence, the extent of which we cannot foresee in advance, the prediction of quantities of mackerel to be taken in the autumn net fishery must be relatively uncertain. For instance, in our forecast for 1932 it was estimated, on the basis of availability during previous autumns, that 500,000 pounds of mackerel of the classes of 1921 and older might be caught, but instead, some 1,400,000 pounds were taken. The excess is to some extent brought about by a larger fleet operating, but the increase in vessels participating in this fishery was not nearly enough to account for the larger catch. On the other hand, the sea water averaged much warmer in 1932, and this, or conditions related to it, we believe, was responsible for the large catch.

Knowing that the yield of this fishery is as much influenced by oceanographic influences as it is by the abundance of mackerel, the only recourse is to determine, as best we may, the trend of availability, estimate its level in 1933, and base the prediction on this, knowing that an unusually warm autumn is likely to produce a much larger catch, and conversely, a cold autumn a smaller catch.

The trend of availability of the older classes among which the 1921 class is dominant, as given in table 2, points toward a reduction in availability of about 10 percent. Assuming the fleet to continue at the same size as in 1932, a catch in 1933 of 300,000 mackerel of these classes is in prospect. This quantity may be caught only if the late autumn temperatures are normal. A warmer autumn would indicate a larger catch and colder autumn, a smaller catch.

1928 class.—Mackerel of this year class have been in all three branches of the vessel fishery in previous years and should reappear in them in 1933. Its numbers are relatively fewer than those of the 1923 class but are far from negligible.

In the seine fishery the 1928 class is the prime example of the transitory type appearing initially at a high level of availability but declining sharply in subsequent years. As was the case with the 1923 class, the decline of the 1928 class was abnormally sharp between 1931 and 1932, and for the same reasons. Hence, it is preferable to take the average annual decline during the period 1929 to 1931 as the normal for this year class. This amounts to 52 percent and would reduce the catch from the level of 1,560,000 mackerel in 1932 to 800,000 mackerel in 1933.

In the net fishery of the spring season the availability of mackerel of the 1928 class doubled between 1930 and 1931, and decreased 10 percent between 1931 and 1932. Since there have been no other year classes of the transitory type observed in the spring fishery of the netting fleet at a comparable age, there is very little evidence from which to gage the change of availability between 1932 and 1933. Judging from previous experience the rate of decline might be double that of the preceding year, and if so a catch of only 70,000 mackerel would be in view.

The number of mackerel of the 1928 class to be caught by the netting fleet in the autumn is contingent upon water temperature as was pointed out in the case of the older classes. Assuming that last year's catch was abnormally high due to the warm autumn and that the real abundance was such as to provide half as large a catch if temperatures had been normal, it is expected that with a normal autumn in 1933 and the same sized fleet fishing as in 1932, the catch should be 120,000 less 10 percent or about 110,000 mackerel.

1929 class.—The class of 1929 has resembled that of 1928 in being of the transitory type. Since it originally was not as large as that of 1928 and has declined rather more sharply during the course of its brief history, its availability during the coming season promises to be practically negligible. Only in the seine fishery are the numbers likely to be sufficient to be considered. When at a comparable age the 1928 class, also of the transitory type, declined 77 percent, but this was in 1932 when the index of availability was affected by unusual abundance of mackerel of the 1930 class; hence, we must conclude that a normal rate of decline at this age would be substantially less. Accordingly, it is estimated that the 1929 class should furnish about

60 percent less mackerel in 1933 than in 1932 when 167,000 were caught. If so, the most probable estimate of catch in 1933 would be only 70,000 mackerel of this class.

1930 class.—Under the assumption followed in this section of "most probable" catch, the 1930 class is being considered as of the persistent type. The evidence supporting this view consists of its resemblance to the 1923 class in registering a distinct increase in availability to the seine fishery as 2-year olds compared to its availability as yearlings during the previous season. This point of resemblance of the two year classes as well as their distinction from the transitory types is shown in figure 7. The estimation of the availability of the 1930 class is complicated by the abnormally low growth rate thus far characterizing this class. Owing to this low growth rate, it does not appear that it will be taken in more than negligible quantities by the spring netting fleet, since heretofore, this method of fishing has seldom taken mackerel much under 1¼ pounds in weight and those of the 1930 class can average only a pound in the spring of 1930. Though they may be considerably larger by autumn, the netting fleet is not expected to take them at that season of the year because one characteristic of the persistent type of year class, which we assume this class to be, is the absence from the catches of the autumn netting fleet. Thus, the 1930 class is to be expected to show only in the seine fishery.

Here it should be extremely important, for if it is of the persistent type, and if the changes in availability of the persistent type are faithfully depicted by the 1923 class as shown in figure 7, the availability of the 1930 class should decline only 11.5 percent in 1933 as compared with last year. Inasmuch as last year the considerable number of 27,500,000 mackerel were caught, reduction of 11.5 percent in availability would indicate the still considerable number of 24,400,000 mackerel in 1933. This is the largest single item in the probable catch of 1933 and the degree to which the catch approaches this estimate will in all likelihood determine the degree to which the catch as a whole approaches the estimate as a whole.

1931 class.—For the purposes of determining the "most probable" catch it is assumed that the 1931 class is of the transitory type. The only reason for considering it such is that this type has occurred more commonly than the persistent type, the ratio of transitory to persistent type being 4 to 1 during the period 1921 to 1929, inclusive. If this ratio is a normal one, it follows that there is also a 4 to 1 chance that the 1931 class is of the transitory type. Having completed only two seasons of growth the mackerel of this class in 1933 will not be large enough to be caught in any number by netters; hence, only the seine catch need be considered.

If the availability of the 1931 class declines at a rate that is average for the transitory type is indicated by the mean decline of the 1927, 1928, and 1929 classes at a comparable age, it may be expected that the availability will be 75 percent less than in 1932. The catch last year being 11,900,000 mackerel, a catch of 3,000,000 mackerel of this class is indicated in 1933.

1932 class.—Up to the end of last season the mackerel of this class had not attained a size that would cause them to be sought by either seiners or netters; hence, there has been no opportunity to gage their availability. For this reason we can offer no estimate of their probable importance in the 1933 catch. During the last eight years the

numbers of yearling mackerel contributed numbers varying from practically zero to 28,800,000 mackerel, and the numbers of yearlings in the 1933 catch may be any number within or beyond this figure. It should be understood that the prediction does not include yearlings and that the estimated totals may be raised by the numbers of yearlings that may be caught during the coming season. These fish will be of tinker size or smaller, and can make no contribution to the catch of mackerel over 1 pound in weight.

Summary, most probable estimate.—In the above paragraphs there have been listed the numbers of mackerel of each year class that are most probable in the 1933 catch in each branch of the fishery. To translate the numbers into poundage, the average weights of each year class, as determined from normal growth curves may be employed for all classes except that of 1930. The growth of the latter has been subnormal thus far, and it is uncertain as to what its future growth rate will be. It may continue to be low, it may be normal, or it may accelerate beyond normal. In computing the poundage of the class for this purpose of the most probable estimate, it appears appropriate to assume a normal growth during 1933, leaving the other possibilities to be covered in the "high" and "low" estimates given in the last sections of this circular. The computations on this basis appear in the last three columns of table 9 and result in a total of 44,080,000, or in round numbers, 44,000,000 pounds.

TABLE 9.—*Estimates of landings by the mackerel fleet in 1933*

[Quantities in thousands of pounds; that is, 000 omitted]

Year classes	High estimate			Low estimate			Most probable estimate		
	By number	Average weight	By weight	By number	Average weight	By weight	By number	Average weight	By weight
Old (mostly 1923):	*Number*	*Pounds*	*Pounds*	*Number*	*Pounds*	*Pounds*	*Number*	*Pounds*	*Pounds*
By seines	3,700	2.14	7,900	3,700	2.14	7,900	3,700	2.14	7,900
By nets, spring	450	2.20	1,000	210	2.20	460	300	2.20	660
By nets, autumn	600	2.30	1,380	150	2.30	340	300	2.30	690
Total	4,750		10,280	4,060		8,700	4,300		9,250
1928:									
By seines	800	1.85	1,480	800	1.85	1,480	800	1.85	1,480
By nets, spring	100	1.85	180	50	1.85	90	70	1.85	130
By nets, autumn	220	1.90	420	60	1.90	110	110	1.90	210
Total	1,120		2,080	910		1,680	980		1,820
1929: By seines	70	1.60	110	70	1.60	110	70	1.60	110
1930: By seines	24,400	1.40	34,200	16,500	1.00	16,500	24,400	1.20	29,300
1931: By seines	29,700	1.20	35,600	3,000	1.20	3,600	3,000	1.20	3,600
Grand total	60,040		82,270	24,540		30,590	32,750		44,080
Offset for effect of availability on fishing time			28,800			4,600			
Corrected total			53,470			35,190			44,080

HIGHEST PROBABLE ESTIMATE

In canvassing the factors which might lead to an availability of mackerel greater than has been outlined in the preceding section, the outstanding consideration has to do with the 1931 class. Instead of being of the transitory type it might possibly turn out to be of the

persistent type, even though the chances against this appear to be about 4 to 1, as has already been pointed out. If it is of this type, and if we may judge by a comparison with the 46 percent increase of the 1923 class and the 264 percent increase of the 1930 class when each of these was at a corresponding age, there should be a substantial increase in availability. Perhaps a fair estimate of this increase would be a value approximately midway between these two examples—say, 150 percent over that of 1932.

There seems to be very little evidence that other year classes to be found in the purse-seine fishery are likely to be more available than has been estimated in the previous section; hence no allowance is made for a larger catch of these classes.

In the net fishery there appears the possibility of some greater availability in the spring season if the bright nights coincide perfectly with the time of greatest abundance. This might cause an availability of as much as 50 percent over the amounts estimated as most probable in the previous section. In the autumn season an even greater allowance for increased availability is necessary to provide for the possibility that an especially warm autumn may render the mackerel much more accessible than they would be in an autumn with normal temperature. It does not appear unlikely that the yield might be double the quantity estimated in the previous section in the event that such a warm autumn is realized in 1933.

It has been pointed out previously that increased availability causes a reduction in amount of time that the fleet spends in actual fishing. In 1932 when this availability increased 29 percent (on a poundage basis) above that of the previous year, the decrease in fishing time was about 15 percent per vessel. Since the catch should be proportional to the fishing effort (at a given level of availability) it is necessary to take this into account. If the estimate of highest probable availability actually is realized, the availability would be 80 percent higher than in 1932, and it would be expected that the reduction of actual fishing time would be more than double the reduction experienced in 1932 when the increase in availability was only 29 percent. We do not know whether the decrease in fishing time is always exactly proportional to the increase in availability, but it would be reasonable to expect this to be the case. If so, the decrease in fishing time in 1933 would be about 35 percent and the estimate based on availability must be reduced by this percentage, making the total highest probable estimate 53,470,000 or in round numbers, 53,000,000 pounds.

LOWEST PROBABLE ESTIMATE

The lowest probable estimate differs from the most probable estimate in being based on the assumption that both the 1930 and 1931 classes are of the transitory type, and as such, their availability in the seine fishery would be due to decrease sharply in 1933 as compared with the previous year. Judging from decreases of other year classes of the transitory type at comparable ages, this would be a reduction of about 40 percent in the 1930 class and 75 percent in the 1931 class. No greater decreases in the remaining year classes than were estimated in the most probable section are contemplated in the seine fishery.

Availability in the net fishery might be reduced in the spring season perhaps by as much as 30 percent by failure of bright nights to coincide with the peak of abundance, and in the autumn, by cool weather, by as much as 50 percent as compared with the availability reckoned in the section on the most probable catch.

The results of computation based on these assumptions appear in table 9 where it may be seen that the availability would be such as to afford a total catch of about 30,600,000 pounds. However, this figure does not allow for an increase in fishing time that would likely result from the lower level of availability. Since this level differs from that of 1932 by about the same amount as the latter differed from 1931 (but in the opposite direction) it should be expected that the fishing time would increase about 15 percent and this should raise the total catch to approximately 35,000,000 pounds.

SUMMARY

In surveying the prospects for the current mackerel season, it has been necessary to consider a great number of items. There has been more or less uncertainty as to the effect of each of these on the outcome of the season. Hence, it might appear that there are countless chances of the catch to depart from the expected quantities. In a sense, this would be a correct impression, for there are numerous respects in which the actual experience may differ from expectations in detail. But the catch, as a whole, depends almost solely on the success or failure of the seine fishery, for it regularly accounts for more than 90 percent of the total mackerel catch; and the size of the catch of the seine fishery hinges almost entirely on the prospective abundance of mackerel of the 1930 and 1931 classes. To be sure, the amount of the contribution of these two classes is uncertain. But there are just three possibilities. Most probable, is that one of them is of the persistent type and will afford a large catch and the other is of the transitory type and will afford a small catch. If so, a total of 44,000,000 pounds is in prospect. The other possibilities, first that both may be of the persistent type and second that both may be of the transitory type, are covered by the highest estimate of 53,000,000 and the lowest estimate of 35,000,000 pounds, respectively. Thus, it appears that the possibilities are well covered by the three estimates.

While the latitude of uncertainty indicated by the extreme estimates at first glance may appear to be quite large, a moment's consideration suffices to indicate that this is not the case. The highest estimate would constitute a 14 percent increase and the lowest would represent a 25 percent decrease as compared with last year's catch. A glance at table 1 will show that during the last 9 years there have been year to year increases of as much as 86 percent and year to year decreases of as much as 31 percent in total catch. So it is obvious that the forecast, even with the latitude it was necessary to allow, fixes the probable change within rather narrow limits relative to the normal fluctuations of the fishery.

Of course, this degree of certainty applies only to changes of catch caused by influences lying within the scope of the prediction. Increases or decreases in the number of vessels participating in the fishery are outside the bounds of the prediction; for it is based solely

on the availability of the mackerel, and does not allow for any changes in fishing effort that might occur. Should the fleet be larger or smaller than in 1932 or should many of the vessels tie up during larger or smaller portions of the season than was the case in 1932, the catch would be correspondingly larger or smaller. Furthermore, the prediction does not include any estimate of the quantities of yearlings that may be caught in 1933. There may be few or many of these in the catch. They should first appear in midsummer at about a half pound in weight (blinks), increasing to three-fourths pound (tinkers) by fall. Any quantity of fish of this category taken in the catch would be additional to the predicted amounts.

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